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CONCERNING A FILING UNDER 35 U.S.C. 371

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INTERNATIONAL APPLICATION NO.

PCT/EP00/01688

INTERNATIONAL FILING DATE

29 FEBRUARY 2000 (29.02.00)

PRIORITY DATE CLAIMED

08 MARCH 1999 (08.03.99)

## TITLE OF INVENTION

PROCESS FOR EVALUATING CODED IMAGES, DEVICE IMPLEMENTING AND PROCESS AND USE OF THE  
DEVICE AND PROCESS

## APPLICANT(S) FOR DO/EO/US

Philippe Bordes and Philippe Guillotel

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
  - a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
  - b. ☒ has been transmitted by the International Bureau.
  - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ A copy of the International Search Report (PCT/ISA/210). attached to Item 13
8. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
  - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
  - b. ☐ have been transmitted by the International Bureau.
  - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
  - d. ☒ have not been made and will not be made.
9. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
10. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
11. ☒ A copy of the International Preliminary Examination Report (PCT/ISA/409).
12. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

## Items 13 to 20 below concern document(s) or information included:

13. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98. with two (2) references attached
14. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☒ Certificate of Mailing by Express Mail 20. Return postcard receipt
20. ☐ Other items or information:

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I hereby certify that this application is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above and is addressed to the Assistant Commissioner for Patents, Washington, D.C. 20231.

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant : Philippe Bordes and Philippe Guillotel

Filed : February 29, 2000 - PCT National Phase of PCT/EP00/01688

For : PROCESS FOR EVALUATING CODED IMAGES, DEVICE  
IMPLEMENTING AND PROCESS AND USE OF THE DEVICE AND PROCESS

PRELIMINARY AMENDMENT

Hon. Commissioner of Patents and Trademarks  
Box PCT  
Washington, D.C. 20231

Sir:

In the US national phase application of PCT/EP00/01688  
please enter the following amendments.

IN THE TITLE:

Please delete the title and insert the new title as published in the  
PCT International Application – PROCESS, DEVICE AND USE FOR  
EVALUATING CODED IMAGES –

IN THE SPECIFICATION:

Please amend the specification as follows:

Page 1, line 4 after the title, insert the following:

--This application claims the benefit under 35 U.S.C. § 365 of  
International Application PCT/EP00/01688, filed February 29, 2000, which  
claims the benefit of French Patent Application No. 9902827, filed March 8,  
1999.--

IN THE CLAIMS:

Please amend the claims as follows. This is the clean version.  
Attached is the marked up version of these claims.

1. Process for evaluating the quality of coded images, wherein it  
comprises:

a) a step of processing the signal representative of the image so as to obtain a processed signal,  
b) a step of constructing on the basis of the signal representative of the coded image, a signal representative of the field of motion image on the basis of the source sequence,  
c) a step of building a signal representative of the segmenting of the field of motion and of storing the image pixels representative of each region having a different field of motion at an address defined with respect to the velocity vectors estimated in the step of constructing the field of motion making it possible to determine the pixels having different velocity vectors,  
d) a step of determining or of calculating a psychovisual human filter to be applied as a function of the estimated velocity of the region,  
e) a step of filtering the processed signal, and  
f) a step of constructing the map of disparities between the signals representative of the image which are obtained after the filtering step and the signals representative of the decoded image which are obtained after the filtering step.

2. Process for evaluating the quality of coded images according to Claim 1, wherein it comprises a step consisting in applying each of the preceding steps to the source image and to the decoded image.

3. Process for evaluating the quality of coded images according to Claim 1, wherein it comprises a step of frequency decomposition of the images (FFT, subband, etc.) which precedes the filtering step and consists of a weighting by a coefficient deduced from curves taking into account the estimated velocity and the frequency band considered, so as to take account of the relative influence of the velocity and of the spatial frequency on the perception of the moving images.

4. Process according to Claim 1, wherein the psychovisual filtering step is applied to matrices representative of the inter-pyramid differences between the Laplace pyramids of the processed source images and those of the processed decoded images after weighting by, on the one hand, the local influence representative of the frequency of the pixel concerned and, on the other hand, a filtering coefficient deduced from filtering curves taking into account the estimated velocity and the frequency band corresponding to the level of the Laplace pyramid to which the pixel belongs in a multiresolution pyramid obtained by constructing a pyramid on the basis of the image of each region of different velocity.

5. Process according to Claim 1, wherein the psychovisual filtering curves are either built from a succession of curves arranged in the form of a database and stored in the system, and possibly interpolation on the basis of these curves, or obtained by analytical representation implemented by calculation means making it possible to calculate each curve.

6. Process according to Claim 4, wherein the step of constructing the map of disparities is performed by recomposing the filtered multiresolution pyramids obtained in the preceding step.

8. Process according to Claim 1, wherein the velocity or local value of the motion is obtained by possible construction of filters followed by application of the filter constructed or by application of a median filter.

9. Process according to Claim 1, wherein it comprises a step of precorrecting the images by performing a Gamma correction and a correction by Weber's law.

10. Process according to Claim 7, wherein the Gamma correction  $\gamma$  is as follows:

$$y = K_S V^{\gamma_S} \text{ with } V = k_a E^{\gamma_a}$$

in which  $y$  is the luminance,  $V$  the luminance voltage,  $E$  the illumination of the illumination analysed image,  $\gamma_s$  is an exponent of around 2.2 for black and white picture tubes and  $\gamma_a$  has a value of 0.45 commonly agreed for colour television.

11. Process according to Claim 1, wherein the filtering is obtained by constructing the psychovisual filter corresponding to the velocity estimated on the basis of a database of filters and interpolation between the two filters corresponding to the regions closest to the region whose velocity has been estimated.

12. Process according to Claim 4, wherein the relative local influence ( $I_n$ ) of the pixel  $p_i$  concerned is obtained by calculating a value  $E_n$  representing the  $q^{\text{th}}$  power of the inter-pyramid level-to-level difference between the source pyramids and decoded pyramids of like level of the pixel concerned.

13. Process according to Claim 12, wherein the calculation of  $I_n$  is performed by using the following formula:

$$I_n = \frac{E_n}{\sum_{k \leq n} m(E_k)}$$

with  $E_n = (\text{Diff}_n(p_{ij}))^q$ ,

$$m(E_k) = E_k \text{ if } E_k > S$$

and  $m(E_k) = S$  if  $E_k < S$

with for example  $S = 0.5\%$  (maximum possible value of  $E_k$ ).

14. Process according to Claim 4, wherein the filtering comprises a directional filtering of the images in a determined direction rather than in another.

15. Process according to Claim 9, wherein the Gamma correction is performed by a calculation device implementing the following equation:

$$L_{display} = L_{max} \left( \frac{e}{e_{max}} \right)^{\gamma}$$

e being the grid level value of the pixel,  $e_{max}$  being the maximum value example 256 if the coding is performed on 8 bits,  $L_{max}$  being the intensity corresponding to  $e_{max}$  in  $cd/m^2$ .

16. Process according to Claim 9, wherein Weber's law is implemented by a calculation device which carries out the following function:

$$V_{out} = \frac{L_{max}}{2} \log_{10} \left( 1 + 100 \frac{L_{display}}{L_{max}} \right)$$

17. Process according to Claim 1, wherein the calculation of the filter is obtained through the following formula:

$$G(\alpha, v) = [6.1 + 7.3 |\log(v/3)|^3] \times v \alpha^2 \exp[-2\alpha(v+2)/45.9]$$

with  $\alpha = 2\pi f$ , f = spatial frequency, v = velocity.

18. Use of the process according to Claim 1, in a coding device, characterized by a dynamic retroaction as a function of the psychovisual disparities calculated by the calculation device implementing the process on one of the parameters used by the coding device in the course of the coding.

19. Use of the process according to Claim 18, wherein the calculated disparities are compared with a threshold so as to modify the coding parameters of the coding apparatus until the desired threshold is overstepped.

20. Use of the process according to Claim 19, wherein one of the parameters is either the quantization interval, or the size of the images, or the form of the group of pictures GOP.

21. Use of the process according to Claim 18, wherein the homogeneity of the calculated disparities is analysed by the calculation device so as to act on the coding parameters of the coding apparatus.

22. Use of the process according to Claim 18, wherein the coding parameters of the different objects of an image whose coding is object oriented are modified as a function of a constant desired disparity.

23. Use of the process according to Claim 18, wherein it consists in performing a dynamic reallocation of the bit rates allocated to a coding apparatus with multiplexing.

24. Device for evaluating the quality of coded images, wherein it comprises:

- a means of processing the signal representative of the source image (10a) and of the decoded image [(10b)] so as to obtain a processed source image signal and a processed decoded image signal,

- means of constructing on the basis of the signal representative of each of the images, a signal representative of the estimating of the field of motion on the basis of each of the images of the source and decoded sequences,

- means of building a signal representative of the segmenting of the field of motion and of storing the image pixels representative of each region  $R_i$  having a different field of motion at an address defined with respect to the velocity vectors estimated in the step of constructing the field of motion making it possible to determine for each of the source and decoded images those having different velocity vectors,

- a means of determining or of calculating a psychovisual human filter to be applied as a function of the estimated velocity of the region,

- means of filtering applied to each of the processed source images and processed decoded images and

- a means of constructing the map of disparities between the signals representative of the processed source image which are obtained after the filtering step and the signals representative of the processed decoded image which are obtained after the filtering step.

25. Device according to Claim 24, wherein the psychovisual filtering means are applied to matrices representative of the inter-pyramid differences calculated by calculation means between the Laplace pyramids of the processed source images and those of the processed decoded images after weighting by, on the one hand, the local influence representative of the frequency of the pixel concerned and, on the other hand, a filtering coefficient deduced from stored or calculated filtering curves and taking into account the estimated velocity and the frequency band corresponding to the level of the Laplace pyramid to which the pixel belongs in a multiresolution pyramid obtained by means of constructing this multiresolution pyramid on the basis of the image of each region of different velocity.

26. Device according to Claim 24, wherein the means of constructing the map of disparities perform a recombination of the filtered multiresolution pyramids.

27. Device according to one of Claim 24, wherein the means of processing, the means of building, the means of determining, the means of constructing, the means of filtering consist of at least one microprocessor associated with memories sufficient to contain the programs making it possible to embody the various means and to contain the databases and the intermediate information necessary for the calculation and for obtaining the map of disparities.

28. Process according to Claim 1, the images being coded according to the MPEG standard, wherein the step of constructing a signal representative of the field of motion image exploits the per-macroblock motion vectors calculated during the coding of the images according to the MPEG standard.

29. Process according to Claim 1, wherein the decoded image is a noisy source image constructed on the basis of the source image to which white noise is added.

30. Use of the process according to Claim 29 for predicting, on the basis of the map of disparities, the regions most sensitive "a priori" to the coding errors and for coding the regions as a function of this prediction.

31. Use of the process according to Claim 29 to perform a prefiltering of the source images as a function of the map of disparities.

32. Use of the process according to Claim 29 for determining locally the amount of information which can be inserted into the images (Watermarking) without this addition being perceptible.

**IN THE ABSTRACT:**

Please add the attached Abstract.

**REMARKS**

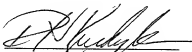
The specification has been amended to include a reference to the priority applications.

The above amendments to the claims have been made to eliminate reference indicia and to meet the requirements of the USPTO.

To meet the requirements of the United States, the Abstract, as filed, has been amended.

No fee is believed to have been incurred by virtue of this amendment. However, if a fee is incurred on the basis of this amendment, please charge such fee against deposit account 07-0832.

Respectfully submitted,  
Philippe Bordes  
Philippe Guillotel



Ronald H. Kurdyla, Attorney  
Registration No. 26,932  
609/734-9701

THOMSON multimedia Licensing Inc.  
Patent Operation  
PO Box 5312, Princeton, NJ 08543-5312

Date: Sept. 7, 2001

### MARKED UP CLAIMS

1. Process for evaluating the quality of coded images, [characterized in that] wherein it comprises:

5 a) a step of processing the signal representative of the image so as to obtain a processed signal,  
b) a step of constructing on the basis of the signal representative of the coded image, a signal representative of the field of motion image on the basis of the source sequence,  
10 c) a step of building a signal representative of the segmenting of the field of motion and of storing the image pixels representative of each region having a different field of motion at an address defined with respect to the velocity vectors estimated in the step of constructing the field of motion making it possible to determine the pixels having different velocity vectors,  
15 d) a step of determining or of calculating a psychovisual human filter to be applied as a function of the estimated velocity of the region,  
e) a step of filtering the processed signal, and  
f) a step of constructing the map of disparities between the signals representative of the image which are obtained after the filtering step  
20 and the signals representative of the decoded image which are obtained after the filtering step.

2. Process for evaluating the quality of coded images according to Claim 1, [characterized in that] wherein it comprises a step consisting in  
25 applying each of the preceding steps to the source image and to the decoded image.

3. Process for evaluating the quality of coded images according to Claim 1, [characterized in that] wherein it comprises a step of frequency decomposition of the images (FFT, subband, etc.) which precedes the filtering step and consists of a weighting by a coefficient deduced from curves taking into account the estimated velocity and the frequency band considered, so as to take account of the relative influence of the velocity and of the spatial frequency on the perception of the moving images.

35 4. Process according to Claim 1, [characterized in that] wherein the psychovisual filtering step is applied to matrices representative of the inter-pyramid differences between the Laplace pyramids of the processed source images and those of the processed decoded images after weighting by, on the one hand, the local influence representative of the frequency of the pixel concerned and, on the other hand, a filtering coefficient deduced from filtering curves taking into account the estimated velocity and the frequency band corresponding to the level of the Laplace pyramid to which the pixel belongs in a multiresolution pyramid obtained by constructing a pyramid on the basis of the image of each region of different velocity.  
40  
45

5. Process according to Claim 1, [characterized in that] wherein the psychovisual filtering curves are either built from a succession of curves



arranged in the form of a database and stored in the system, and possibly interpolation on the basis of these curves, or obtained by analytical representation implemented by calculation means making it possible to calculate each curve.

6. Process according to Claim 4, [characterized in that] wherein the step of constructing the map of disparities is performed by recomposing the filtered multiresolution pyramids obtained in the preceding step.

7. Process according to Claim 4 [or 6], [characterized in that] wherein the step of processing the image comprises a step of decomposing the source and decoded images into a Laplace pyramid of n levels and a step of constructing the inter-pyramid difference.

8. Process according to Claim 1, [characterized in that] wherein the velocity or local value of the motion is obtained by possible construction of filters followed by application of the filter constructed or by application of a median filter.

9. Process according to Claim 1 [or 4], [characterized in that] wherein it comprises a step of precorrecting the images by performing a Gamma correction and a correction by Weber's law.

10. Process according to Claim 7, [characterized in that] wherein the Gamma correction  $\gamma$  is as follows:

$$y = K_S V^{\gamma_S} \text{ with } V = k_E E^{\gamma_E}$$

in which y is the luminance, V the luminance voltage, E the illumination of the illumination analysed image,  $\gamma_S$  is an exponent of around 2.2 for black and white picture tubes and  $\gamma_E$  has a value of 0.45 commonly agreed for colour television.

11. Process according to Claim 1, [characterized in that] wherein the filtering is obtained by constructing the psychovisual filter corresponding to the velocity estimated on the basis of a database of filters and interpolation between the two filters corresponding to the regions closest to the region whose velocity has been estimated.

12. Process according to Claim 4, [characterized in that] wherein the relative local influence ( $I_n$ ) of the pixel  $p_i$  concerned is obtained by calculating a value  $E_n$  representing the  $q^{\text{th}}$  power of the inter-pyramid level-to-level difference between the source pyramids and decoded pyramids of like level of the pixel concerned.

13. Process according to Claim 12, [characterized in that] wherein the calculation of  $I_n$  is performed by using the following formula:

$$I_n = \frac{E_n}{\sum_{k \in n} m(E_k)}$$

with  $E_n = (\text{Diff}_n(p_0))^q$ ,  
 $m(E_k) = E_k$  if  $E_k > S$   
and  $m(E_k) = S$  if  $E_k < S$

with for example  $S = 0.5\%$  (maximum possible value of  $E_k$ ).

14. Process according to Claim 4, [characterized in that] wherein the filtering comprises a directional filtering of the images in a determined direction rather than in another.

15. Process according to Claim 9, [characterized in that] wherein the Gamma correction is performed by a calculation device implementing the following equation:

$$L_{display} = L_{\max} \left( \frac{e}{e_{\max}} \right)^\gamma$$

e being the grid level value of the pixel,  $e_{\max}$  being the maximum value example 256 if the coding is performed on 8 bits,  $L_{\max}$  being the intensity corresponding to  $e_{\max}$  in  $\text{cd/m}^2$ .

16. Process according to Claim 9, [characterized in that] wherein Weber's law is implemented by a calculation device which carries out the following function:

$$V_{\text{out}} = \frac{L_{\max}}{2} \text{Log}_{10} \left( 1 + 100 \frac{L_{display}}{L_{\max}} \right)$$

17. Process according to Claim 1 [or 4], [characterized in that] wherein the calculation of the filter is obtained through the following formula:

$$G(\alpha, v) = [6.1 + 7.3 |\log(v/3)|^3] \times v \alpha^2 \exp[-2\alpha(v + 2)/45.9]$$

with  $\alpha = 2\pi f$ ,  $f$  = spatial frequency,  $v$  = velocity.

18. Use of the process according to [one of the preceding claims] Claim 1, in a coding device, characterized by a dynamic retroaction as a function of the psychovisual disparities calculated by the calculation device implementing the process on one of the parameters used by the coding device in the course of the coding.

19. Use of the process according to Claim 18, [characterized in that] wherein the calculated disparities are compared with a threshold so as to modify the coding parameters of the coding apparatus until the desired threshold is overstepped.

20. Use of the process according to Claim 19, [characterized in that] wherein one of the parameters is either the quantization interval, or the size of the images, or the form of the group of pictures GOP.

21. Use of the process according to Claim 18, [characterized in that] wherein the homogeneity of the calculated disparities is analysed by the calculation device so as to act on the coding parameters of the coding apparatus.

22. Use of the process according to [the preceding claims] Claim 18, [characterized in that] wherein the coding parameters of the different objects of an image whose coding is object oriented are modified as a function of a constant desired disparity.

23. Use of the process according to [Claims 18 to 22] Claim 18, [characterized in that] wherein it consists in performing a dynamic reallocation of the bit rates allocated to a coding apparatus with multiplexing.

24. Device for evaluating the quality of coded images, [characterized in that] wherein it comprises:

- a means [(1a, 1b)] of processing the signal representative of the source image (10a) and of the decoded image [(10b)] so as to obtain a processed source image signal and a processed decoded image signal,

- means [(2a, 2b)] of constructing on the basis of the signal representative of each of the images, a signal representative of the estimating of the field of motion on the basis of each of the images of the source and decoded sequences,

- means [(3a, 3b)] of building a signal representative of the segmenting of the field of motion and of storing the image pixels representative of each region  $R_i$  having a different field of motion at an address defined with respect to the velocity vectors estimated in the step of constructing the field of motion making it possible to determine for each of the source and decoded images those having different velocity vectors,

- a means [(4, 5)] of determining or of calculating a psychovisual human filter to be applied as a function of the estimated velocity of the region,

- means [(6a, 6b)] of filtering applied to each of the processed source images and processed decoded images and

- a means [(7)] of constructing the map of disparities between the signals representative of the processed source image which are obtained after the filtering step and the signals representative of the processed decoded image which are obtained after the filtering step.

25. Device according to Claim 24, [characterized in that] wherein the psychovisual filtering means are applied to matrices representative of the inter-pyramid differences calculated by calculation means between the Laplace pyramids of the processed source images and those of the processed decoded images after weighting by, on the one hand, the local

influence representative of the frequency of the pixel concerned and, on the other hand, a filtering coefficient deduced from stored or calculated filtering curves and taking into account the estimated velocity and the frequency band corresponding to the level of the Laplace pyramid to which the pixel belongs in a multiresolution pyramid obtained by means of constructing this

multiresolution pyramid on the basis of the image of each region of different velocity.

26. Device according to Claim 24, [characterized in that] wherein the means of constructing the map of disparities perform a recomposition of the filtered multiresolution pyramids.

27. Device according to one of [Claims 24 to 26] Claim 24, [characterized in that] wherein the means of processing, the means of building, the means of determining, the means of constructing, the means of filtering consist of at least one microprocessor associated with memories sufficient to contain the programs making it possible to embody the various means and to contain the databases and the intermediate information necessary for the calculation and for obtaining the map of disparities.

28. Process according to Claim 1, the images being coded according to the MPEG standard, [characterized in that] wherein the step of constructing a signal representative of the field of motion image exploits the per-macroblock motion vectors calculated during the coding of the images according to the MPEG standard.

29. Process according to Claim 1, [characterized in that] wherein the decoded image is a noisy source image constructed on the basis of the source image to which white noise is added.

30. Use of the process according to Claim 29 for predicting, on the basis of the map of disparities, the regions most sensitive "a priori" to the coding errors and for coding the regions as a function of this prediction.

31. Use of the process according to Claim 29 to perform a prefiltering of the source images as a function of the map of disparities.

32. Use of the process according to Claim 29 for determining locally the amount of information which can be inserted into the images (Watermarking) without this addition being perceptible.

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## PROCESS, DEVICE AND USE FOR EVALUATING CODED IMAGES

5 The present invention relates to a process and a device for evaluating the quality of coded images as well as to the use of such a process and a device.

In systems for coding digital video sequences, it is known practice to estimate the quality of the images output by the procedure by comparison with the original image, using the signal-to-noise ratio.

10 This ratio is generally termed the PSNR (Peak Signal to Noise Ratio) and obtained by summing the quadratic differences of the pixels of the final image and of the original image.

However, this measure does not take into account the psychovisual characteristics of human vision (HVS: Human Visual System).  
15 Indeed, the human eye is more sensitive to certain spatial frequencies and its perception of the details of objects is strongly linked with their relative motion and also with the phenomena of luminosity and contrast.

Thus a sequence, which can, according to the traditional quality estimation procedure, appear as the outcome of good coding and be  
20 assumed to have a good image quality, will not be perceived in this manner by the observer, given his psychovisual characteristics.

The object of the invention is therefore to allow assessment of the quality of images which approximates as closely as possible to the perception which the observer will have thereof.

25 The influence of the human factor (HVS) is partially taken into account in traditional coders of MPEG2 type in the perception of the spatial frequencies of the decoded images by using a weighting matrix on the high frequencies of the 8 by 8 image blocks, but absolutely no account is taken as regards the perception of the details of objects in motion.

30 Most of the studies which measure the disparities between two images are essentially based on a static analysis of the defects taking no account of motion, or else on an analysis of the spatial frequencies.

Additionally, the few prior studies which take the temporal aspect into consideration, but take no account of the motion proper, use the  
35 difference (distortion) between a current macroblock and the macroblock in the same position in the preceding image.

None of these studies considers the influence of human vision together with the problems of motion in the image.

The purpose of the invention is to alleviate the drawbacks of the prior art.

This purpose is achieved by the fact that the process for evaluating the quality of images comprises:

a) a step of processing the signal representative of the image so as to obtain a processed signal,

b) a step of constructing on the basis of the signal representative of the coded image, a signal representative of the field of motion image on the basis of the source sequence,

c) a step of building a signal representative of the segmenting of the field of motion and of storing the image pixels representative of each region having a different field of motion at an address defined with respect to the velocity vectors estimated in the step of constructing the field of motion making it possible to determine the pixels having different velocity vectors,

d) a step of determining or of calculating a psychovisual human filter to be applied as a function of the estimated velocity of the region,

e) a step of filtering the processed signal, and

f) a step of constructing the map of disparities between the signals representative of the image which are obtained after the filtering step and the signals representative of the decoded image which are obtained after the filtering step.

According to another particular feature, the process for evaluating the quality of images comprises a step consisting in applying each of the steps to the source image and to the decoded image.

According to another particular feature, the process for evaluating the quality of coded images comprises a step of frequency decomposition of the images (FFT, subband, etc.) which precedes the filtering step and consists of a weighting by a coefficient deduced from curves taking into account the estimated velocity and the frequency band considered, so as to take account of the relative influence of the velocity and of the spatial frequency on the perception of the moving images.

According to another particular feature, the psychovisual filtering step is applied to matrices representative of the inter-pyramid differences between the Laplace pyramids of the processed source images and those of the processed decoded images after weighting by, on the one hand, the

local influence representative of the frequency of the pixel concerned and, on the other hand, a filtering coefficient deduced from filtering curves taking into account the estimated velocity and the frequency band corresponding to the level of the Laplace pyramid to which the pixel belongs in a  
 5 multiresolution pyramid obtained by constructing a pyramid on the basis of the image of each region of different velocity.

According to another particular feature, the psychovisual filtering curves are either built from a succession of curves arranged in the form of a database and stored in the system, and possibly interpolation on the basis of  
 10 these curves, or obtained by analytical representation implemented by calculation means making it possible to calculate each curve.

According to another particular feature, the step of constructing the map of disparities is performed by recomposing the filtered multiresolution pyramids obtained in the preceding step.

15 According to another particular feature, the step of processing the image comprises a step of decomposing the source and decoded images into a Laplace pyramid of  $n$  levels and a step of constructing the inter-pyramid difference.

20 According to another particular feature, the velocity or local value of the motion is obtained by possible construction of filters followed by application of the filter constructed or by application of a median filter.

According to another particular feature, the process comprises a step of precorrecting the images by performing a Gamma correction and a correction by Weber's law.

25 According to another particular feature, the Gamma correction is performed by a device implementing the following formula:

$$y = KS V^\gamma$$

with  $V = kaE^{\gamma_a}$

30 in which  $y$  is the luminance,  $V$  the luminance voltage,  $E$  the illumination of the analysed image  $\gamma$  is an exponent of around 2.2 for black and white picture tubes and  $\gamma_a$  has a value of 0.45 commonly agreed for colour television.

35 According to another particular feature, the filtering is obtained by constructing the psychovisual filter corresponding to the velocity estimated on the basis of a database of filters and interpolation between the two filters corresponding to the regions closest to the region whose velocity has been estimated.



According to another particular feature, the relative local influence ( $I_n$ ) of the pixel  $p_i$  concerned is obtained by calculating a value  $E_n$  representing the  $q^{\text{th}}$  power of the inter-pyramid level-to-level difference between the source pyramids and decoded pyramids of like level of the pixel concerned.

According to another particular feature, the calculation of  $I_n$  is performed by using the following formula:

$$I_n = \frac{E_n}{\sum_{k \in n} m(E_k)}$$

with  $E_n = (\text{Diff}_n(p_{ij}))^q$ ,

$m(E_k) = E_k$  if  $E_k > S$

and  $m(E_k) = S$  if  $E_k < S$

with for example  $S = 0.5\%$  (maximum possible value of  $E_k$ ).

According to another particular feature, the filtering comprises a directional filtering of the images in a determined direction rather than in another.

According to another particular feature, the Gamma correction is performed by a calculation device implementing the following equation:

$$L_{display} = L_{max} \left( \frac{e}{e_{max}} \right)^{\gamma}$$

$e$  being the grid level value of the pixel,  $e_{max}$  being the maximum value example 256 if the coding is performed on 8 bits,  $L_{max}$  being the intensity corresponding to  $e_{max}$  in  $\text{cd/m}^2$ .

According to another particular feature, Weber's law is implemented by a calculation device which carries out the following function:

$$v_{out} = \frac{L_{max}}{2} \text{Log}_{10} \left( 1 + 100 \frac{L_{display}}{L_{max}} \right)$$

According to another particular feature, the calculation of the psychovisual filter is obtained by a device implementing the following formula:

$$G(\alpha, v) = [6.1 + 7.3(\log(v/3))^3] \times v \alpha^2 \exp(-2\alpha(v + 2)/45.9)$$

with  $\alpha = 2\pi f$ ,  $f$  = spatial frequency,  $v$  = velocity.

Another purpose of the invention is to propose a use of the process according to the invention.

This other purpose is achieved by the fact that the process of the invention is used in a coding device, by a dynamic retroaction as a function of the psychovisual disparities calculated by the calculation device implementing the process of one of the parameters used by the coding device in the course of the coding.

According to another particular feature, the calculated disparities are compared with a threshold so as to modify the coding parameters of the coding apparatus until the desired threshold is overstepped.

According to another particular feature, one of the coding parameters is either the quantization interval, or the size of the images, or the form of the group of pictures GOP.

According to another particular feature, the process of the invention is used in the analysis of the homogeneity of the calculated disparities so as to act on the coding parameters.

According to another particular feature, the process of the invention is used to modify the coding parameters of the different objects of an image whose coding is object oriented as a function of a constant desired disparity.

According to another particular feature, the process of the invention is used to perform a dynamic reallocation of the allocated bit rates.

A last purpose of the invention is to propose a device implementing the process.

This purpose is achieved by the fact that the evaluating device comprises:

- a means (1a, 1b) of processing the signal representative of the source image (10a) and of the decoded image (10b) so as to obtain a processed source image signal and a processed decoded image signal,

- means (2a, 2b) of constructing on the basis of the signal representative of each of the images, a signal representative of the estimating of the field of motion on the basis of each of the images of the source and decoded sequences,

- means (3a, 3b) of building a signal representative of the segmenting of the field of motion and of storing the image pixels representative of each region  $R_i$  having a different field of motion at an address defined with respect to the velocity vectors estimated in the step of constructing the field of motion making it possible to determine for each of the source and decoded images those having different velocity vectors,

- a means (4, 5) of determining or of calculating a psychovisual human filter to be applied as a function of the estimated velocity of the region,

5 - means (6a, 6b) of filtering applied to each of the processed source images and processed decoded images and

- a means (7) of constructing the map of disparities between the signals representative of the processed source image which are obtained after the filtering step and the signals representative of the processed decoded image which are obtained after the filtering step.

10 According to another particular feature, the psychovisual filtering means are applied to matrices representative of the inter-pyramid differences calculated by calculation means between the Laplace pyramids of the processed source images and those of the processed decoded images after weighting by, on the one hand, the local influence  
15 representative of the frequency of the pixel concerned and, on the other hand, a filtering coefficient deduced from stored or calculated filtering curves and taking into account the estimated velocity and the frequency band corresponding to the level of the Laplace pyramid to which the pixel belongs in a multiresolution pyramid obtained by means of constructing this  
20 multiresolution pyramid on the basis of the image of each region of different velocity.

According to another particular feature, the means of constructing the map of disparities perform a recomposition of the filtered multiresolution pyramids.

25 According to another particular feature, the means of processing, the means of building, the means of determining, the means of constructing, the means of filtering consist of at least one microprocessor associated with memories sufficient to contain the programs making it possible to embody the various means and to contain the databases and the intermediate  
30 information necessary for the calculation and for obtaining the map of disparities.

Other particular features and advantages of the present invention will become more clearly apparent on reading the description given hereinbelow with reference to the appended figures in which:

35 - Figure 1a represents a schematic view of the steps of a first variant of the process,

- Figure 1b represents a graphic representation of the result of the preprocessing steps,

- Figure 1c represents a simplified view of the source image matrix,

5 - Figure 1d represents a simplified view of the matrix obtained after segmenting the field of motion,

- Figure 2 represents a schematic view of the various steps of a second variant of the process,

10 - Figure 3 represents the family of filtering curves corresponding to the psychovisual influence of human vision, which curves are stored in a database for determined velocities,

- Figure 4 represents the multiresolution pyramid,

- Figure 5 represents the Laplace pyramid.

A first variant embodiment of the invention will be explained with  
15 the aid of Figure 1a in which the steps carried out, by the device allowing the evaluation of the quality of the images at the output of a coding procedure, are obtained through various devices which process, on the one hand the signals from a source image (10a) and on the other hand the signals representative of a decoded image (10b). Each image is represented by a  
20 plurality of pixels  $p_{ij}$  arranged as a matrix, as represented in Figure 1c, and whose size depends on the definition desired for the image. To a given pixel  $p_{ij}$  there corresponds a size of characteristic details, which is expressed as a function of the size of the matrix defining the number of pixels in the image, on the one hand by the frequency in cycles and on the other hand by the  
25 velocity in degrees per second. Each of the steps of the process according to the first variant embodiment is applied both to the source image and to the decoded image. The expression decoded image should be understood to mean any video image obtained at the output of a coding decoding device allowing transmission according to a standard such as, for example, MPEG.  
30 To fix matters better, the reader may also refer to appendix 1 which represents the various steps numbered from 1 to 7 of the process implemented according to the first variant.

A first device (1a, 1b) for preprocessing source images (10a) and  
35 decoded images (10b) makes it possible to implement a first step of processing termed the preprocessing step carrying out a Gamma correction of the signals representative of the image and a correction of the contrast by a Weber law. Weber's law takes account of the fact that the eye is sensitive

to contrasts and that when gazing at a light spot of intensity  $I + dI$  on a background having a luminous intensity  $I$ , the ratio  $dI/I$ , called Weber's ratio, is practically constant at around 2% over a wide luminous threshold range, except for the very low luminous intensities and the very high luminous intensities. The correction of contrast takes into account a form of saturation of the eye linked with the fact that, for example, a zone of average intensity alongside a zone of high intensity will be less well distinguished than a zone of low intensity alongside a zone of average intensity.

To take this effect into account, the voltage signal which will control the luminous intensity of the display performed by the cathode-ray tube is corrected by a so-called Weber law expressed hereinbelow:

$$V_{out} = \frac{L_{max}}{2} \log_{10} \left( 1 + 100 \frac{L_{display}}{L_{max}} \right)$$

in which  $L_{max}$  represents the maximum luminous intensity approximately equal to one hundred candela per square metre ( $L_{max} \approx 100 \text{ cd/m}^2$ ) and  $L_{display}$  the desired luminous intensity.

This mathematical law is implemented by an electronic device making it possible to perform these calculations. By way of example, such a device can be built from a microprocessor associated with memories which contain the program corresponding to the calculation algorithm.

For its part, the Gamma correction makes it possible to obviate the response of the television, that is to say the characteristics of the tube allowing display. Indeed, cathode-ray tube display devices are nonlinear devices and the light intensity reproduced on the screen of a cathode-ray monitor is not, in the absence of correction, proportional to its input voltage. Gamma correction is a procedure for compensating for this nonlinearity so as to obtain correct and proportional reproduction of the corresponding luminous intensity at the input voltage. The image from a screen is subdivided into pixels organized as a matrix in which the position of the pixel  $p_{ij}$  is defined by the indices  $i$  and  $j$  of the matrix. The value  $p_{ij}$  of the pixel is representative of the desired intensity. To correct the phenomena linked with the cathode-ray tube, a correction law which corresponds to the following equation:

$$L_{display} = L_{max} \left( \frac{e}{e_{max}} \right)^{\gamma}$$

is applied to this value representative of the voltage intended to obtain the desired luminous intensity, Gamma ( $\gamma$ ) having a value of between 2.3 and 2.6 depending on the particular features of the cathode-ray tube. In this formula,  $e$  is the grid level of the value of the pixel  $p_{ij}$ ,  $e_{\max}$  is the maximum possible value of  $e$ , for example 256, if the control signals are expressed on 8 bits, and  $L_{\max}$  is the intensity corresponding to  $e_{\max}$  in  $\text{cd/m}^2$ ,  $L_{\max}$  being approximately equal to  $100 \text{ cd/m}^2$ .

Another formulation of the Gamma law can be as follows:

$$y = K_s V^\gamma$$

with  $V = kaE^\gamma$

in which  $y$  is the luminance,  $V$  the luminance voltage,  $E$  the illumination of the analysed image,  $\gamma$  is an exponent of around 2.2 for black and white picture tubes and  $\gamma_a$  corresponds to a value of 0.45 commonly agreed for colour television,  $K_s$  and  $ka$  proportionality coefficients.

This Gamma correction and Weber operation makes it possible to transform the pixel value received as input to the preprocessing circuit (1a) into a final value  $P'_{ij} = I_g (P_{ij})_{P_{ij}} \cdot I_g$  which follows the law corresponding to curve 1 represented in Figure 1b. Each of the source images (10a) gives rise to a plurality of preprocessed pixels  $p'_{aij}$  and each of the decoded images (10b) likewise gives rise to a second plurality of preprocessed pixels  $p'_{bij}$ .

In parallel with this processing operation, a second step (2a, 2b, Fig. 1) of so-called motion estimation which allows the construction for each source and decoded image of the field of motion image, is implemented on the basis of each image sequence. This construction of the field of motion is performed between  $t$  and  $t-1$  by conventional calculations, such as those calling upon the method explained in the book published by Don Pearson, MacGraw Hill Book Company and entitled "Image processing" "The Essex series in telecommunication and information systems", page 47 et seq. This estimation of motion over a sequence of images can use either the differential method, or the method of block matching, or the Fourier method or the method of estimation in three-dimensional space. For each image, a certain number of motion vectors ( $v_i$ ) are thus obtained and the image can thus be partitioned into regions ( $R_1, \dots, R_i, v_i, \dots, R_n, v_n$ , Fig. 1d) based on the motion information, each region ( $R_i, v_i$ ) is therefore characterized by the fact that all the pixels of this region have a single associated velocity vector ( $v_i$ ). This splitting of the image into constant velocity regions constitutes a third step (3a, 3b) of so-called segmentation of the field of motion, applied to each

source and decoded image. A field of motion is therefore rendered homogeneous by virtue of the segmentation technique and the nearby pixels of motion are grouped into one and the same region. This field of motion thus segmented is then closer to the true motion of the objects of the scene represented by the images. This homogenization thus makes it possible to perform a slight denoising and to have a reduced number of different motions corresponding to a small number of velocities  $v_{li}$ , thereby reducing the number of filters to be calculated and to be stored in the next step so as to avoid having  $(255)^2$  motions to be calculated and to be stored in the context of an image consisting of  $255 \times 255$  pixels  $p_{ij}$ . The estimation of the motion can also use the technique relying on the extraction of particular objects in the scene, such as edges or corners of objects consisting in following the motion of these particular elements from one image to another. This provides information regarding motion at different locations of the image and an interpolation procedure is used to assign motion vectors to the remaining image areas. One way of measuring the motions of the angles or edges of elements consists in applying a high pass filter to the image so as to isolate the edges and thereafter to use the technique relying on the method of differentials to measure the value of the motion. The formation of borders can be attenuated with the aid of a low pass filter so as to reduce the effects of noise and allow the measurement of large motions. A low pass filter can, for example, be built for a matrix space of dimension 3-3 via the following matrix:

1	1	1
1	1	1
1	1	1

A high pass filter can, for example, be built for a matrix space of dimension 3-3 via the following matrix:

-0.125	-0.125	-0.125
-0.125	1	-0.125
-0.125	-0.125	-0.125

Thus, a table giving for an estimated velocity  $v$  the pixels  $p_{ij}$  of the image which belong to this region having this estimated velocity  $v$  in cycles per degree is stored in the form of the matrix of Figure 1d in the storage means of the device for segmenting the field of motion with a view to the subsequent use thereof.

The procedure is continued via a fourth step implemented in parallel for each of the source (10a) and decoded (10b) images consisting in constructing a psychovisual filter (4a, 4b) for each. This fourth step is performed, for example, using a database of filter curves comprising a plurality of curves such as those represented in Figure 3 expressing the influence of the human factor  $H$  as a function of the velocity of the motion  $v_i$  and of the spatial frequency  $f_i$ . To these values  $v_i$ ,  $f_i$  there corresponds a filtering value  $H$ . If the velocity  $v_i$  lies between the velocities  $v_1$  and  $v_2$  of two curves ( $Hv_1$ ,  $Hv_2$ ), the device performs an interpolation so as to determine the corresponding value  $H$ . This interpolation can, for example, be linear. This step can also be performed by direct calculation of the value  $H$  for a given velocity on the basis of an analytical model of the psychovisual influence. The analytical model of the filter can, for example, be represented by the following formula:

$$G(\alpha, v) = [6.1 + 7.3 |\log(v/3)|^3] \times v \alpha^2 \exp[-2\alpha(v + 2)/45.9] \text{ with } \alpha = 2\pi f.$$

In the fifth step, the device synthesizes a filtering value  $h(s, v)$  in the spatial domain for each filtering value  $H(f_s, v)$  in the frequency domain and associated with a velocity  $v$  and a frequency  $f_s$  by applying an inverse fast Fourier transform ( $\text{FFT}^{-1}$ ) to the filtering values  $H(f_s, v)$  in the frequency domain, this being expressed by the expression  $h(s, v) = \text{FFT}^{-1}[H(f_s, v)]$  where  $f_s$  represents the characteristic size of the details in cycles per degree,  $v$  their motion expressed in duration per second and  $s$  the resolution.

The value  $h$  thus determined of the spatial domain for each source image (5a) and decoded image (5b) in the fifth step will be applied in the course of a sixth step (6a, respectively 6b) to each of the preprocessed pixels  $p'_{aij}$  of the source image emanating from the preprocessing and of the decoded image  $p'_{bij}$  emanating from the preprocessing.

On each occasion, this sixth filtering step (6a, 6b) results in a pair of filtered pixel values  $p'_{afij}$  and  $p'_{bfij}$  which is thereafter used in a last step (7) of constructing a matrix of disparities ( $D_{isp}$ ) by calculating the quadratic error between each pair of pixel values.

$$D_{isp} = (p'_{afij} - p'_{bfij})^n \text{ with } n = 2 \text{ or other}$$



This matrix will thus give an objective assessment of the distortions perceptible to the human eye which are introduced by the coding decoding procedure which one wishes to estimate.

The second variant embodiment of the invention will now be explained in conjunction with Figure 2 which represents the various means allowing the implementation of the process according to this second variant. To fix matters better, the reader may also refer to appendix 2 which represents the various steps numbered from 1 to 11 of the process implemented according to the second variant and which also represents the decrease in size obtained through the operations of constructing the Laplace pyramids.

In this variant, the first four steps of the first variant are applied to the source image (10a), namely the precorrection (1a), the construction of motion fields (2a) and the segmentation (3a) as well as the construction of the psychovisual filter (4a). The pixels  $p_{aij}$  originating from the processing of the source image (10a) and resulting from the preprocessing step and the pixels  $p_{bij}$  resulting from the step of preprocessing the decoded image (10b) are each subjected in a step (5.1a and respectively 5.1b) to a  $\frac{1}{2}$  decimation filtering ( $F_{1/2}$ ). This filtering is a low pass filtering which makes it possible on the basis of a matrix of pixels representing an image  $P_{n-1}$  of a given level  $n-1$  to obtain the image  $P_n$  of next level  $n$ . This is expressed by the relation:

$$P_n = F_{1/2}(P_{n-1}) \text{ with } n > 0$$

$P_0$  being the original image.

By way of example the decimation filter can be built for a 3-3 matrix space via the following matrix:

1	2	1
2	4	2
1	2	1

This operation of  $\frac{1}{2}$  decimation filtering by a calculation device has the result of reducing a matrix of pixels of size  $m \times n$  representing the source image  $P_{s0}$  to a level 1 matrix  $P_{s1}$  of size  $m/2 \times n/2$ , the matrix  $P_{sn}$  of level  $n$  being of size  $m/2^n \times n/2^n$ . Likewise, this  $\frac{1}{2}$  decimation filtering operation has the result of reducing a matrix of pixels of size  $m \times n$  representing the decoded or corrupted image  $P_{d0}$  to a level 1 matrix  $P_{d1}$  of size  $m/2 \times n/2$ , the matrix  $P_{dn}$  of level  $n$  being of size  $m/2^n \times n/2^n$ . Therefore,

for each source and decoded image, the calculation device stores the level  $n$  and the next level  $n + 1$  in its memory.

Thereafter, in the next step (5.2a, respectively 5.2b), the calculation device deducts from each image  $P_n$  of level  $n$ , the image  $P_{n+1}$ , of immediately succeeding level, expanded by 2 ( $E_2$ ) so as to obtain what is referred to appropriately as a succession of matrices constituting what is referred to appropriately as a Laplace pyramid  $Ln$ , according to the formula:

$$L_n = P_n - E_2(P_{n+1}) \text{ for } n < N$$

with  $L_N = P_N$ .

The expansion operation performed by  $E_2$  consists in interpolating the image  $P_{n+1}$  (of size  $m/2 \times n/2$ ) to obtain an image of size  $m \times n$ .

This expansion or interpolation operation involves several interpolation matrices as a function of the position of the pixel to be interpolated.

This makes it possible to build, for the source image, a pyramid  $LS_n$  of stored matrices and for the decoded or corrupted image a second pyramid  $LD_n$  of stored matrices. Depending on the choice of the filter  $F_{1/2}$ , the image  $LS_n$  obtained at the end of the above step is a good approximation of the energy included within a frequency band centred around the value  $f_n = 1/(n + 1)$ . For further details regarding Laplace pyramids or so-called Gaussian pyramids and regarding expansion matrices, the reader may refer to the article "the Laplacian pyramid as a compact code image" published in the journal IEEE transactions on communications VOL. COM. 31, No. 4, April 1983 pages 532 to 540 authors P.J. Burt and Ed. H. Adelson.

The Laplace pyramids ( $LS_n$ ,  $LD_n$ ) are obtained via steps (5.2a. and 5.2b).

In the next step, the device constructs, on the basis of the regions ( $R_{vi}$ ) characterized by the same velocity vector ( $v_i$ ) and defined at the output of the motion field segmentation step (3) applied to the source image, a multiresolution pyramid  $R_n$  of the region image, starting from the original region image  $R_0$  and by applying to this original region image  $R_0$  a  $1/2$  decimation median filter  $G_{1/2}$  according to the formula:

$$R_n = G_{1/2}(R_{n-1})$$

$R_0$  = the original region image.

For further teaching regarding the building of a median filter known to the person skilled in the art, the reader may refer to chapter 4 of the book entitled "nonlinear digital filters, principles and applications"

published in 1990 by Kluwer Academic Publishers, by I. Pitas and A.N. Venetsopoulos.

The (multiresolution) motion pyramid is produced only for the source image (10a) and the value of the pixel of  $LS_n$  and  $LD_n$  represent the energy which there is in a frequency band whereas via  $R_n$  one has the motion.

In this step, the calculation device does not perform the calculation corresponding to step 5.2, that is to say to the subtraction of the image  $R_n$  corresponding to each level  $n$  from the image  $R_{n+1}$  of the immediately succeeding level  $n+1$  expanded by 2. At this calculation step, the matrices constituting the multiresolution pyramid are stored and make it possible to obtain for each pixel of each level  $n$  of  $R_n$  a local value of the motion. The median filter of a window of  $n \times m$  pixels is obtained by ranking the values of the pixels and by retaining the pixel having the median value.

The application of the median filter  $G_{1/2}$  to the matrix of pixels  $R_n$  of dimension  $m \times n$  makes it possible to obtain a matrix  $R_{n+1}$  of dimension  $m/2 \times n/2$ . The decimation operation is included in that of the median filter. The median filter has the same effect on the images  $R_n$  as the filter  $F_{1/2}$  on the images  $P_n$ : it reduces their size by 2 horizontally and vertically, except that instead of being a conventional matrix filter, this is a "median" filter, that is to say one based on an analysis of the local statistics.

The Laplace pyramids ( $LS_n$ ,  $LD_n$ ) calculated in step 5.2 are thereafter used in a step, represented in step 7, of calculating the level-to-level inter-pyramid differences according to the formula:

$$\text{Diff}_n = LS_n - LD_n.$$

This makes it possible to obtain matrices  $\text{Diff}_n$ , each coefficient of which expresses the values of the differences of the coefficients of the matrices of the source Laplace pyramid ( $LS_n$ ) and decoded Laplace pyramid ( $LD_n$ ) for the same level  $n$  and to do so for each level from 0 to  $n$ . In the Laplace pyramid  $LS_n$  the value of the pixel represents the energy which there is in a frequency band. The frequency disparity between the two images is obtained for a given frequency band by taking the inter-pyramid difference  $LS_n - LD_n$ .

This result is in fact weighted by the sensitivity of the eye for this frequency which is expressed by the relation of the relative influence of the activity of the frequency  $f_n$ . This relative influence of the activity of the frequency  $f_n$  can be masked by a large activity in the higher frequencies. To

determine and take into account this relative influence of the activity in a masking step (8), the calculation device begins by evaluating the local influence  $E_n$  of a pixel  $p_{ij}$ , which is defined by the value of the result of the calculation of the inter-pyramid differences, applied to the pixel  $p_{ij}$ , this result being raised to the power  $q$ :

$$E_n = (\text{Diff}_n(p_{ij}))^q,$$

this local influence value allows the calculation device to determine a matrix expressing the relative influence of the activity through a circuit which implements the following formula:

$$I_n = \frac{E_n}{\sum_{k \in n} m(E_k)}$$

with  $m(E_k) = E_k$  if  $E_k > S$

and  $m(E_k) = S$  if  $E_k < S$

with for example  $S = 0.5\%$  (maximum possible value of  $E_k$ ).

As in the previous variant, the calculation device performs a filtering step 4 by using a database (BD) containing a plurality of filtering curves expressing the influence of the human factor on the visual perception of the images. These filtering curves make it possible, on the basis of the values of the frequency and of velocity corresponding to a pixel  $p_{ij}$  to determine a weighting coefficient  $H$  for this pixel. Thus, for each pixel  $p_{ij}$  of the matrix  $L_n$  corresponding to a velocity region  $R_n$ , the calculation device determines a value  $H$  which will weight the relative influence  $I_n$ . This weighting step (9) is obtained through a calculation device implementing the equation:

$$T_n(p_{ij}) = I_n(p_{ij}) \times H$$

The implementation of this equation makes it possible to obtain a pyramid of matrices. When the program of the calculation device selects a pixel from a matrix of level  $n$  of the Laplace pyramid, to this level  $n$  there corresponds a spatial frequency  $f_n$  and the calculation device is able to associate that pixel of the image  $R_n$  to which there corresponds a velocity value  $v$ . By using databases and curves recorded in these databases, the calculation device determines either directly, or by interpolation between two curves, the value of the gain coefficient  $H$ . In this second method, one works directly on objects (Laplace pyramids) which correspond to frequency quantities. There is therefore no need to switch to the spatial domain, since all the calculations are carried out in the frequency domain. This value  $H$  will

weight the relative influence of the activity ( $I_n$ ). This weighting step (9) makes it possible to obtain a pyramid of matrices to which may be applied an optional step (10) catering for directional filtering so as to take account of the psychovisual directions favoured by the human gaze.

- 5 Thus, it is possible to filter the images constituted by the matrices  $T_n$  through directional filters favouring one direction with respect to others, these filters consisting of matrices of coefficients of dimension  $n \times n$  corresponding to the dimension of the image factor  $T_n$ . An example of a  $0^\circ$  directional filter matrix is given below for a dimension  $5/5$ .

10

0	0	0	0	0
0	0	0	0	0
0.094	0.141	0.28	0.141	0.094
0	0	0	0	0
0	0	0	0	0

An example of a  $90^\circ$  directional filter matrix is given below.

0	0	0.125	0	0
0	0	0.188	0	0
0	0	0.375	0	0
0	0	0.188	0	0
0	0	0.125	0	0

15

An example of a  $45^\circ$  directional filter matrix is given below.

0.016	0	0	0	0
0	0.023	0	0	0
0	0	0.047	0	0
0	0	0	0.023	0
0	0	0	0	0.016

20

The result of this directional filtering step (10) is sent to a summator circuit so as in a step (11) to recompose the multiresolution pyramids  $P'_n$  via the equation

$$P'_n = E_2 (P'_{n+1}) + T_n \quad (n < N)$$

with  $P'_N = T_N$

This therefore yields

$$P'_{N-1} = E_2 (T_N) + T_{N-1}$$

5           The procedure is repeated iteratively to obtain  $P'_0$  which represents the matrix constituting the map of disparities.

These steps of the two variant embodiments of the invention are implemented with the aid of microprocessor circuits executing the appropriate programs making it possible to carry out the steps set out earlier.

10       These circuits also comprise storage means for storing, moreover, programs to be executed, the matrices of pixels or the matrices of regions or again the intermediate results making it possible to expect the next calculation step or again the filters to be applied to the intermediate or final results.

15       This is used to compare the subjective performance of various coder apparatuses or again to compare the subjective performance of various coding algorithms and/or to measure the perception of artefacts due to image processing. Depending on this performance, the calculation circuit implementing one of the two variant embodiments of the invention can modify the coding by, for example, retroacting the measurement of  
20       subjective quality of the coded images thus performed on the global and/or local parameters of the coding. A global parameter on which the retroaction may be performed can, for example, be the mean bit rate and a local parameter can, for example, be the local quantization interval used during the coding. This retroaction can be dynamic during coding, the errors  
25       retroacting on the local quantization interval, the size of the images, the form of the GOP (Group of pictures) etc. The retroaction can also be performed iteratively in the case of codings for video disc (DVD) or CD-ROM. In this case, so long as the error is above a threshold and/or is not homogeneous over the whole image, the retroaction of the calculation circuit operates a  
30       decrease in the severity of the coding parameters globally and/or locally. So long as the error is below a threshold, the measurement of the subjective quality of the images performed by the calculation circuit makes it possible to increase the severity of the coding parameters.

35       Lastly, a penultimate use of the method of estimating or of measuring the subjective quality of a sequence of images emanating from a coder can relate to object oriented coding. In this case, the use of the calculation device of one of the methods implemented by this device makes

it possible to ensure a constant subjective quality of the various objects of the scene or to ensure a given inter-object relative subjective quality. Lastly, the estimation process and device can make it possible to modify the conditions of dynamic reallocation of the bit rates allocated to each of the channels of a broadcast with statistical multiplexing so as to ensure a given and homogeneous subjective quality of the programmes broadcast.

Other modifications within the scope of the person skilled in the art also form part of the spirit of the invention.

A variant embodiment of the invention consists in using, as signal representative of the estimation of the field of motion, the per-macroblock motion vectors emanating from the procedure for coding/decoding the decoded image, for example during the MPEG-type coding.

Another variant embodiment of the invention consists in replacing the decoded image by a noisy source image. The latter can be constructed for example on the basis of the source image to which white noise is added (random variable uniform in all the spatial frequency bands). The disparity maps obtained can then be regarded as a prediction of the zones of the image where the coding errors will be most perceptible "a priori", that is to say before having performed the coding proper.

These disparity maps may then be used in the implementation of devices for preprocessing the source images for the purpose of preventing the generation of artefacts or coding defects during a future coding procedure. A preprocessing device consists for example of a circuit for prefiltering and/or for reducing the energy in the high frequencies, in the zones of the image where the visibility of the coding artefacts is lowest, zones supplied by the disparity maps.

These "a priori" disparity maps can be used to further reduce the bit rate necessary for coding in the zones where the visibility of the coding artefacts is predicted to be lower "a priori".

These "a priori" disparity maps can also be used to locally measure the amount of "hidden" information which can be inserted into the source or decoded images without being perceptible (Watermarking).

## APPENDIX 1

Method 1

- 5 Step 1 *Precorrection of images*: Gamma Correction of the screen and Contrast Correction (Weber's law).
- Step 2 *Construction of the Field of Motion* image based on the Source Sequence and for each image.
- 10 Step 3 *Segmentation of the Field of Motion*. For each image, a Segmentation into Regions is thus available, based on the Motion information. Each *Region(v)* is therefore characterized by a velocity vector *v*. Each pixel of each image (Source or Decoded) belongs to a Region corresponding to an estimated velocity *v* (in cycles per degree).
- 15 Step 4 For each *Region(v)*, *Construction of the corresponding Psychovisual Filter*, on the basis of a BDD filter  $\{ H(f_s, v) \}_{i=1, \dots, N}$  and interpolation of the filters.
- 20 Step 5 For each *Region(v)*, *Synthesis of the Spatial Filter* by inverse FFT:  

$$h(s, v) = FFT^{-1}[H(f_s, v)]$$
- Step 6 *Filtering of the Source and Decoded images* to obtain two other images:
- 25 SourceF and DecodedF.  
Each pixel P of the Source/Decoded image is filtered by the Filter  $h(s, v)$ , corresponding to the *Region(v)* to which P belongs, centred on P and applied to the Source/Decoded image.
- 30 Step 7 *Construction of the Map of Disparities or psychovisual Errors*  

$$Err = (SourceF - DecodedF)^n \quad (n = 2, \text{ or other})$$



## APPENDIX 2

Method 2

Step 1 (see Method 1).

5

Step 2 (see Method 1).

Step 3 (see Method 1).

10 Step 4 (see Method 1).

Step 5 Decomposition of the Source and Decoded images into a *Laplace Pyramid* of N levels constructed in two steps:

15

- Each level  $P_n$  is firstly obtained by  $\frac{1}{2}$  Decimation-Filtering (low-pass) of the immediately preceding level (multiresolution pyramid, Figure 4).

$$P_n = F_{1/2}(P_{n-1}) \quad n > 0$$

$$P_0 = \text{original image}$$

20

- Then from each level  $P_n$  is deducted the immediately succeeding level expanded by 2 so as to obtain  $L_n$  (Laplace pyramid, Figure 5).

$$L_n = P_n - E_2(P_{n+1}) \quad n < N$$

$$L_N = P_N$$

25

This calculation makes it possible to obtain a representation of a multiresolution pyramid  $P_n$  in accordance with Figure 4 and a representation of a Laplace pyramid  $L_n$  in accordance with Figure 5.

If the Filter  $F_{1/2}$  is well chosen, the image  $L_n$  is a good approximation of the energy included within a frequency band centred around

30

$$f_n = 1/(n + 1).$$

Finally, two Laplace Pyramids are available:  $LS_n$  (Source) and  $LD_n$  (Decoded).

35

Step 6 By the same principle, the multiresolution Pyramid  $R_n$  of the Regions image is constructed by replacing  $F_{1/2}$  by  $G_{1/2}$   $\frac{1}{2}$  Decimation/median Filter. Thus, for each pixel of each level of the Laplace Pyramids (Step 5), the local value of the motion is available.

Step 7 Calculation of the level-to-level inter-Pyramid Differences:

$$Diff_n = LS_n - LD_n$$

5 Step 8 Application of the *principle of frequency masking* (Texture/Masking):

The relative influence of the activity at the frequency  $f_n$  is masked by considerable activity in the higher frequencies ( $f_k < n$ ).

The relative local influence of pixel  $pi$ ,  $I_n(pi)$  is then defined by:

$$I_n = \frac{E_n}{\sum_{k < n} m(E_k)} \text{ with: } E_n = (Diff_n(pi))^q$$

10 with  $q = 2$  for example.

Step 9 *Filtering of the Source and Decoded Laplace Pyramids.*

Each pixel  $pi$  of  $L_n$  is weighted by the value  $H(f_n, v)$ , corresponding to the Region(v) to which  $pi$  belongs in  $R_n$ , and by the relative influence  $I_n$ .

15  $T_n(pi) = I_n(pi) \times H$

Step 10 Directional Filtering: to take account of the psychovisual directions favoured by the human gaze, it is possible to filter the images  $T_n$  by directional filters which favour one direction with respect to others.

20 Step 11 *Construction of the Map of Disparities or psychovisual Errors:* the multiresolution pyramids  $P'_n$  are recomposed:

$$P'_n = E_2(P'_{n+1}) + T_n \quad (n < N)$$

$$P'_N = T_N$$

25 The Map of disparities corresponds to  $P'_0$ .

CLAIMS

1. Process for evaluating the quality of coded images, characterized in that it comprises:

5 a) a step of processing the signal representative of the image so as to obtain a processed signal,

b) a step of constructing on the basis of the signal representative of the coded image, a signal representative of the field of motion image on the basis of the source sequence,

10 c) a step of building a signal representative of the segmenting of the field of motion and of storing the image pixels representative of each region having a different field of motion at an address defined with respect to the velocity vectors estimated in the step of constructing the field of motion making it possible to determine the pixels having different velocity vectors,

15 d) a step of determining or of calculating a psychovisual human filter to be applied as a function of the estimated velocity of the region,

e) a step of filtering the processed signal, and

20 f) a step of constructing the map of disparities between the signals representative of the image which are obtained after the filtering step and the signals representative of the decoded image which are obtained after the filtering step.

2. Process for evaluating the quality of coded images according to Claim 1, characterized in that it comprises a step consisting in applying each of the preceding steps to the source image and to the decoded image.

25 3. Process for evaluating the quality of coded images according to Claim 1, characterized in that it comprises a step of frequency decomposition of the images (FFT, subband, etc.) which precedes the filtering step and consists of a weighting by a coefficient deduced from curves taking into account the estimated velocity and the frequency band considered, so as to take account of the relative influence of the velocity and of the spatial frequency on the perception of the moving images.

30 4. Process according to Claim 1, characterized in that the psychovisual filtering step is applied to matrices representative of the inter-pyramid differences between the Laplace pyramids of the processed  
35 source images and those of the processed decoded images after weighting by, on the one hand, the local influence representative of the frequency of the pixel concerned and, on the other hand, a filtering coefficient deduced

from filtering curves taking into account the estimated velocity and the frequency band corresponding to the level of the Laplace pyramid to which the pixel belongs in a multiresolution pyramid obtained by constructing a pyramid on the basis of the image of each region of different velocity.

5. Process according to Claim 1, characterized in that the psychovisual filtering curves are either built from a succession of curves arranged in the form of a database and stored in the system, and possibly interpolation on the basis of these curves, or obtained by analytical representation implemented by calculation means making it possible to calculate each curve.

6. Process according to Claim 4, characterized in that the step of constructing the map of disparities is performed by recomposing the filtered multiresolution pyramids obtained in the preceding step.

7. Process according to Claim 4 or 6, characterized in that the step of processing the image comprises a step of decomposing the source and decoded images into a Laplace pyramid of  $n$  levels and a step of constructing the inter-pyramid difference.

8. Process according to Claim 1, characterized in that the velocity or local value of the motion is obtained by possible construction of filters followed by application of the filter constructed or by application of a median filter.

9. Process according to Claim 1 or 4, characterized in that it comprises a step of precorrecting the images by performing a Gamma correction and a correction by Weber's law.

10. Process according to Claim 7, characterized in that the Gamma correction  $\gamma$  is as follows:

$$y = K_S V^{\gamma_s} \text{ with } V = k_a E^{\gamma_a}$$

in which  $y$  is the luminance,  $V$  the luminance voltage,  $E$  the illumination of the illumination analysed image,  $\gamma_s$  is an exponent of around 2.2 for black and white picture tubes and  $\gamma_a$  has a value of 0.45 commonly agreed for colour television.

11. Process according to Claim 1, characterized in that the filtering is obtained by constructing the psychovisual filter corresponding to the velocity estimated on the basis of a database of filters and interpolation between the two filters corresponding to the regions closest to the region whose velocity has been estimated.

12. Process according to Claim 4, characterized in that the relative local influence ( $I_n$ ) of the pixel  $p_i$  concerned is obtained by calculating a value  $E_n$  representing the  $q^{\text{th}}$  power of the inter-pyramid level-to-level difference between the source pyramids and decoded pyramids of like level of the pixel concerned.

13. Process according to Claim 12, characterized in that the calculation of  $I_n$  is performed by using the following formula:

$$I_n = \frac{E_n}{\sum_{k \leq n} m(E_k)}$$

with  $E_n = (\text{Diff}_n(p_{ij}))^q$ ,

$m(E_k) = E_k$  if  $E_k > S$

and  $m(E_k) = S$  if  $E_k < S$

with for example  $S = 0.5\%$  (maximum possible value of  $E_k$ ).

14. Process according to Claim 4, characterized in that the filtering comprises a directional filtering of the images in a determined direction rather than in another.

15. Process according to Claim 9, characterized in that the Gamma correction is performed by a calculation device implementing the following equation:

$$L_{display} = L_{max} \left( \frac{e}{e_{max}} \right)^{\gamma}$$

$e$  being the grid level value of the pixel,  $e_{max}$  being the maximum value example 256 if the coding is performed on 8 bits,  $L_{max}$  being the intensity corresponding to  $e_{max}$  in  $\text{cd/m}^2$ .

16. Process according to Claim 9, characterized in that Weber's law is implemented by a calculation device which carries out the following function:

$$v_{out} = \frac{L_{max}}{2} \log_{10} \left( 1 + 100 \frac{L_{display}}{L_{max}} \right)$$

17. Process according to Claim 1 or 4, characterized in that the calculation of the filter is obtained through the following formula:

$$G(\alpha, v) = [6.1 + 7.3 |\log(v/3)|^3] \times v^2 \exp[-2\alpha(v+2)/45.9]$$

with  $\alpha = 2\pi f$ ,  $f$  = spatial frequency,  $v$  = velocity.

18. Use of the process according to one of the preceding claims in a coding device, characterized by a dynamic retroaction as a function of the psychovisual disparities calculated by the calculation device implementing

the process on one of the parameters used by the coding device in the course of the coding.

19. Use of the process according to Claim 18, characterized in that the calculated disparities are compared with a threshold so as to modify the coding parameters of the coding apparatus until the desired threshold is overstepped.

20. Use of the process according to Claim 19, characterized in that one of the parameters is either the quantization interval, or the size of the images, or the form of the group of pictures GOP.

21. Use of the process according to Claim 18, characterized in that the homogeneity of the calculated disparities is analysed by the calculation device so as to act on the coding parameters of the coding apparatus.

22. Use of the process according to the preceding claims, characterized in that the coding parameters of the different objects of an image whose coding is object oriented are modified as a function of a constant desired disparity.

23. Use of the process according to Claims 18 to 22, characterized in that it consists in performing a dynamic reallocation of the bit rates allocated to a coding apparatus with multiplexing.

24. Device for evaluating the quality of coded images, characterized in that it comprises:

- a means (1a, 1b) of processing the signal representative of the source image (10a) and of the decoded image (10b) so as to obtain a processed source image signal and a processed decoded image signal,

- means (2a, 2b) of constructing on the basis of the signal representative of each of the images, a signal representative of the estimating of the field of motion on the basis of each of the images of the source and decoded sequences,

- means (3a, 3b) of building a signal representative of the segmenting of the field of motion and of storing the image pixels representative of each region  $R_i$  having a different field of motion at an address defined with respect to the velocity vectors estimated in the step of constructing the field of motion making it possible to determine for each of the source and decoded images those having different velocity vectors,

- a means (4, 5) of determining or of calculating a psychovisual human filter to be applied as a function of the estimated velocity of the region,

- means (6a, 6b) of filtering applied to each of the processed source images and processed decoded images and

- 5       - a means (7) of constructing the map of disparities between the signals representative of the processed source image which are obtained after the filtering step and the signals representative of the processed decoded image which are obtained after the filtering step.

25.       Device according to Claim 24, characterized in that the psychovisual filtering means are applied to matrices representative of the inter-pyramid differences calculated by calculation means between the Laplace pyramids of the processed source images and those of the processed decoded images after weighting by, on the one hand, the local influence representative of the frequency of the pixel concerned and, on the other hand, a filtering coefficient deduced from stored or calculated filtering curves and taking into account the estimated velocity and the frequency band corresponding to the level of the Laplace pyramid to which the pixel belongs in a multiresolution pyramid obtained by means of constructing this multiresolution pyramid on the basis of the image of each region of different velocity.

26.       Device according to Claim 24, characterized in that the means of constructing the map of disparities perform a recombination of the filtered multiresolution pyramids.

27.       Device according to one of Claims 24 to 26, characterized in that the means of processing, the means of building, the means of determining, the means of constructing, the means of filtering consist of at least one microprocessor associated with memories sufficient to contain the programs making it possible to embody the various means and to contain the databases and the intermediate information necessary for the calculation and for obtaining the map of disparities.

28.       Process according to Claim 1, the images being coded according to the MPEG standard, characterized in that the step of constructing a signal representative of the field of motion image exploits the per-macroblock motion vectors calculated during the coding of the images according to the MPEG standard.

29.       Process according to Claim 1, characterized in that the decoded image is a noisy source image constructed on the basis of the source image to which white noise is added.

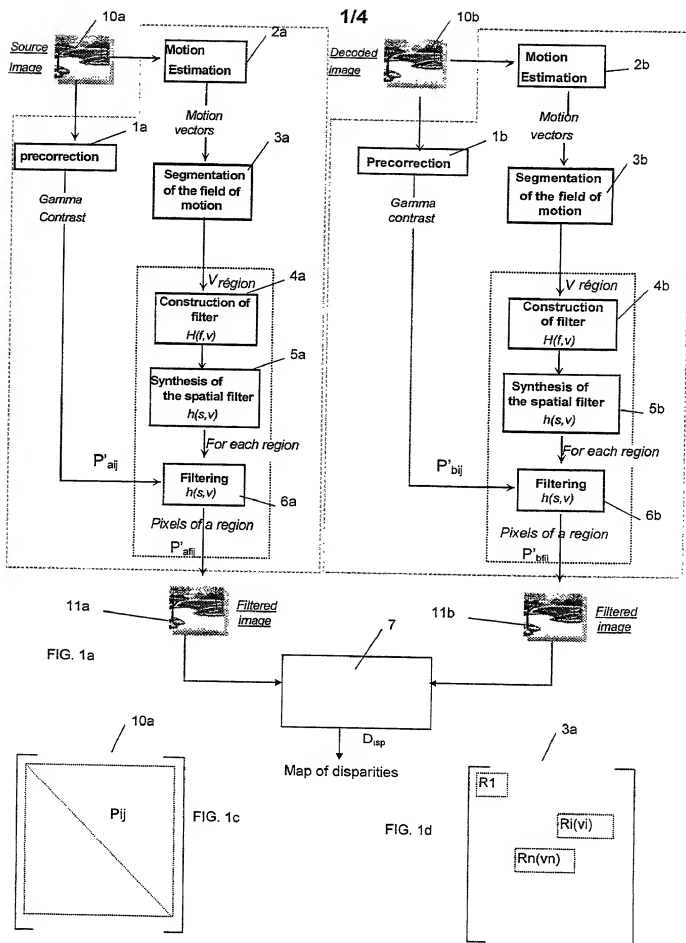
30. Use of the process according to Claim 29 for predicting, on the basis of the map of disparities, the regions most sensitive "a priori" to the coding errors and for coding the regions as a function of this prediction.

31. Use of the process according to Claim 29 to perform a prefiltering  
5 of the source images as a function of the map of disparities.

32. Use of the process according to Claim 29 for determining locally the amount of information which can be inserted into the images (Watermarking) without this addition being perceptible.



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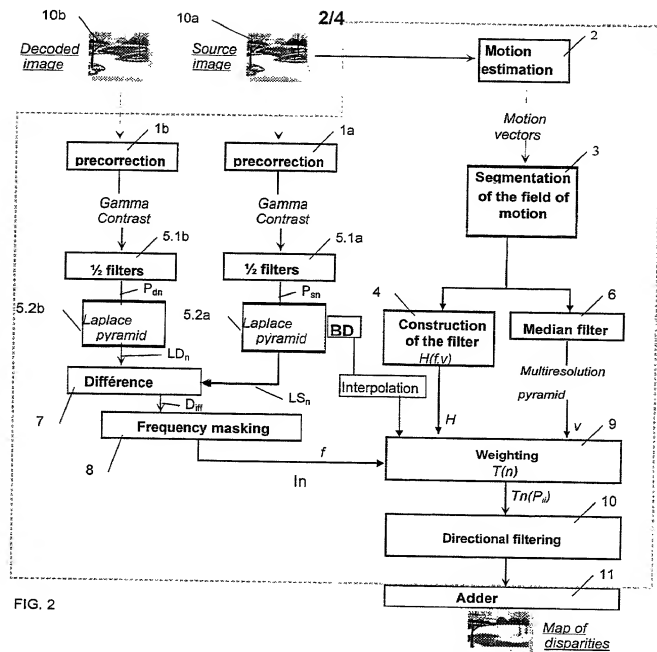


FIG. 2

 $\bigwedge^H$ 

FIG. 3

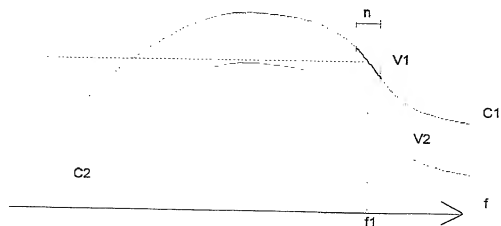
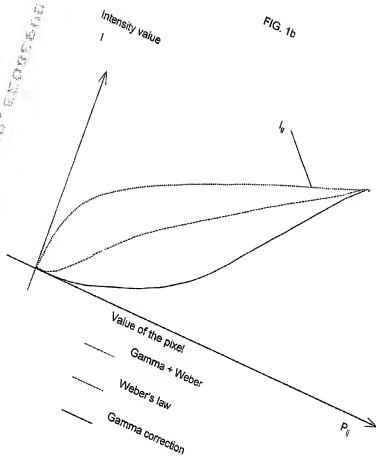


FIG. 1b



4/4



FIG. 4

level-0

level-1

level-2



FIG. 5

0936033.00704

Exp. Label: EL 68244283445

- 1 -

PF990005

DECLARATION FOR UNITED STATES PATENT APPLICATION,  
POWER OF ATTORNEY, DESIGNATION OF CORRESPONDENCE ADDRESS

As a below named inventor, I hereby declare that my residence, post office address and citizenship are as stated below next to my name, and that I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

PROCESS FOR EVALUATING CODED IMAGES, DEVICE IMPLEMENTING THE PROCESS AND  
USE OF THE DEVICE AND PROCESS

the specification of which

(CHECK ONE) ☐ is attached hereto.  
☒ was filed on February 29, 2000, Application Serial. No. PCT/EP00/01688 and was amended on.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with 37 CFR 1.56(a).

I hereby claim foreign priority benefits under 35 USC 119 of any foreign application(s) for patent, utility model, design or inventor's certificate having a filing date before that of the application(s) on which priority is claimed:

Prior Foreign Application(s)			Priority Claimed	
Number	Country	Date Filed	Yes	No
9902827	FR	March 8, 1999	xx	

I hereby claim the benefit under 35 USC 120 of any US Application(s) listed below, and, insofar as the subject matter of each of the claims of this Application is not disclosed in the prior US application in the manner provided by the first paragraph of 35 USC 112, I acknowledge the duty to disclose information which is material to the examination of this application in accordance with 37 CFR 1.56(a).

Serial No.: \_\_\_\_\_ Filed: \_\_\_\_\_

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that wilful false statements and the like so made are punishable by fine or imprisonment, or both, under of 18 USC 1001 and that such wilful false statements may jeopardize the validity of the application or any patent issued thereon.

I hereby appoint the following attorneys to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith: Joseph S. Tripoli (Reg. No. 26,040), Dennis H. Irlbeck (Reg. No. 28,372), Eric Herrmann (Reg. No. 29,169) and Joseph J. Laks (Reg. No. 27,914); Telephone: (609) 734-9813.

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